SURFACE VEHICLE STANDARD

J1704™	MAR2024
Issued 1997-01 Revised 2024-03 Superseding J1704 SEP2019	

Motor Vehicle Brake Fluid Based Upon Glycols,
Glycol Ethers, and the Corresponding Borates

RATIONALE

This document has been revised to include the new reference fluid RM-66-07 and new EPDM rubber RM-69-02. Reinstated 5.11.2, Effect on rubber for EPDM. Added Appendix G for low-temperature freezer use. Revised gas chromatographic analysis method for RM-71. A new test is introduced for determining a fluid's resistance to friction-induced noise based on DIN 51834-5 using a tribometer.

1. SCOPE

This SAE Standard covers motor vehicle brake fluids of the nonpetroleum type, based upon glycols, glycol ethers, and borates of glycol ethers, and appropriate inhibitors for use in the braking system of any motor vehicle, such as a passenger car, truck, bus, or trailer. These fluids are not intended for use under arctic conditions. These fluids are designed for use in braking systems fitted with rubber cups and seals made from styrene-butadiene rubber (SBR) or a terpolymer of ethylene, propylene, and a diene (EPDM).

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE, ASTM, ISO, and DIN publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J75 Motor Vehicle Brake Fluid Container Compatibility

SAE J527 Brazed Double Wall Low-Carbon Steel Tubing

SAE J1703 Motor Vehicle Brake Fluid

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D34-08 Standard Guide for Chemical Analysis of White Pigments

ASTM D91 Test Method for Precipitation Number of Lubricating Oils

ASTM D344 Method of Test for Relative Dry Hiding Power of Paints

ASTM D395 Test Methods for Rubber Property - Compression Set

ASTM D412 Test Methods for Rubber Properties in Tension

ASTM D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)

ASTM D664 Test Method for Neutralization Number of Potentiometric Titration

ASTM D792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

ASTM D865 Test Method for Rubber - Deterioration by Heating in Air (Test Tube Enclosure)

ASTM D1120 Method of Test for Boiling Point of Engine Coolants

ASTM D1209 Test Method for Color of Clear Liquids (Platinum-Cobalt Pigments)

ASTM D1364 Test Method for Water in Volatile Solvents (Fischer Reagent Titration Method)

ASTM D1415 Method of Test for International Hardness of Vulcanized Natural Rubber and Synthetic Rubbers

ASTM D1613 Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer, and Related Products

ASTM D2137 Standard Test Methods for Rubber Property - Brittleness Point of Flexible Polymers and Coated Fabrics

ASTM D2240 Method of Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer

ASTM D3182 Recommended Practice for Rubber - Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets

ASTM D3185 Methods for Rubber - Evaluation of SBR (Styrene-Butadiene Rubber) Including Mixtures with Oil

ASTM E1 Specification for ASTM Thermometers

ASTM E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

ASTM E260 Standard Recommended Practice for General Gas Chromatography Procedure

ASTM E298 Standard Test Methods for Assay of Organic Peroxides

2.1.3 Federal Motor Vehicle Safety Standards (FMVSS) Publications

FMVSS 116 Motor Vehicle Brake Fluids

2.1.4 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 37 Rubber, vulcanized or thermoplastic - Determination of tensile stress-strain properties

ISO 48-4 Rubber, vulcanized or thermoplastic - Determination of hardness - Part 4: Indentation hardness by durometer method (Shore hardness)

ISO 2081 Metallic and other inorganic coatings - Electroplated coatings of zinc with supplementary treatments on iron or steel

ISO 3574 Cold-reduced carbon steel sheet of commercial and drawing qualities

ISO 4520 Chromate conversion coatings on electroplated zinc and cadmium coatings

ISO 4926 Road vehicles - Hydraulic braking systems - Non-petroleum-based reference fluid

ISO 1183-1 Plastics - Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pycnometer method and titration method

ISO 7619-2 Rubber, vulcanized or thermoplastic - Determination of indentation hardness - Part 2: IRHD pocket meter method

2.1.5 DIN Publications

Copies of these documents are available online at www.din.de/en/.

DIN 51834-5 Testing of lubricants - Tribological test in the translatory oscillation apparatus - Part 5: Quantification of the friction-induced noise development of brake fluids in EPDM-steel contacts

3. MATERIALS

The quality of the materials used shall be such that the resulting product will conform to the requirements of this standard and ensure uniformity of performance.

4. REQUIREMENTS

Requirements are given in Table 1 using the test procedures according to Section 5.

Table 1 - SAE J1704 test procedures and requirements

Test Procedure Section	Test Description	Unit	Requirements	
			Standard	Low Viscosity
5.1	**Equilibrium Reflux Boiling Point (ERBP)**	°C	≥230	≥250
5.2	**Wet Equilibrium Reflux Boiling Point (WERBP)**	°C	≥155	≥165
5.3	**Viscosity**			
5.3.1	at -40 °C	mm²/s	≤1500	≤750
5.3.2	at 100 °C	mm²/s	≥1.5	
5.4	**pH Value**	--	7.0 to 11.5	
5.5	**Fluid Stability**			
5.5.1	High-Temperature Stability	°C	±5	
5.5.2	Chemical Stability	°C	±5	
5.6	**Metal Corrosion**			
5.6 .1	Wet Fluid Corrosion Metal Strip Characteristics, After Test Weight Change of Metal Strips		Maximum	
	Tinned Iron	mg/cm²	±0.2	
	Steel	mg/cm²	±0.2	
	Aluminum	mg/cm²	±0.1	
	Cast Iron	mg/cm²	±0.2	
	Brass	mg/cm²	±0.4	
	Copper	mg/cm²	±0.4	
	Zinc-Plated Steel	mg/cm²	±0.4	
	Appearance	--	No pitting or roughness outside contact area	
	Staining and Discoloration	--	Permitted	
	Liquid Characteristics, After Test			
	Appearance	--	No gelling or crystalline deposit	
	pH Value	--	7.0 to 11.5	
	Sediment	%	≤0.1	
	Rubber Characteristics, After Test			
	SBR (RM-03a)			
	Blisters or Sloughing	--	None	
	Hardness Decrease, Maximum	IRHD	15	
	Base Diameter Increase, Maximum	mm	1.4	
	EPDM (RM-69-02)			
	Blisters or Sloughing	--	None	
	Hardness Decrease, Maximum	IRHD	10	
	Volume Increase	%	≤10	
5.6.2	Dry Fluid Corrosion (Fluid As Received) - Metal Strip Characteristics, After Test Weight Change of Metal Strips		Maximum	
	Tinned Iron	mg/cm²	±0.2	
	Steel	mg/cm²	±0.2	
	Aluminum	mg/cm²	±0.1	
	Cast Iron	mg/cm²	±0.2	
	Brass	mg/cm²	±0.4	
	Copper	mg/cm²	±0.4	
	Zinc-Plated Steel	mg/cm²	±0.4	
	Appearance	--	No pitting or roughness outside contact area	
	Staining and Discoloration	--	Permitted	

Test Procedure Section	Test Description	Unit	Requirements
	Liquid Characteristics, After Test		
	Appearance	--	No gelling or crystalline deposit
	pH Value	--	7.0 to 11.5
	Sediment	%	≤0.1
	Rubber Characteristics, After Test		
	SBR (RM-03a)		
	Blister		None
	Sloughing		None
	EPDM (RM-69-02)		
	Blister		None
	Sloughing		None
5.7	**Fluidity and Appearance at Low Temperatures**		
5.7.1	At -40 °C		
	Stratification	--	None
	Sedimentation/Crystallization	--	None
	Bubble Inversion Time	s	≤10
	Appearance at Room Temperature	--	As original
5.7.2	At -50 °C		
	Stratification	--	None
	Sedimentation/Crystallization	--	None
	Bubble Inversion Time	s	≤35
	Appearance at Room Temperature	--	As original
5.8	**Water Tolerance**		
5.8.1	At -40 °C		
	Stratification	--	None
	Sedimentation/Crystallization	--	None
	Appearance	--	Contrast lines on hiding power chart to be discernible when viewed through fluid.
	Bubble Inversion Time	s	≤10
5.8.2	At 60 °C		
	Stratification	--	None
	Sedimentation	% vol	≤0.05
	Sediment in Commercial Packaged Fluid	% vol	≤0.15
5.9	**Compatibility**		
5.9.1	At -40 °C		
	Stratification	--	None
	Sedimentation/Crystallization	--	None
	Appearance	--	Contrast lines on hiding power chart to be discernible when viewed through fluid.
5.9.2	60 °C		
	Stratification	--	None
	Sedimentation	% vol	≤0.05
5.10	**Resistance to Oxidation**		
	Metal Appearance	--	No pitting or roughness outside contact area. No more than trace of gum.
	Staining/Discoloration	--	Permitted
	Weight Loss of Aluminum	mg/cm²	≤0.05
	Weight Loss of Cast Iron	mg/cm²	≤0.3
5.11	**Effect on Rubber**		
5.11.1	Styrene Butadiene Rubber (SBR) RM-03a		
	At 120 °C		
	Hardness Decrease	IRHD	0 to 15

Test Procedure Section	Test Description	Unit	Requirements
	Base Diameter Increase	mm	0.15 to 1.4
	Blisters	--	None
	Sloughing	--	None
5.11.2	Ethylene Propylene Diene Monomer (EPDM) RM-69-02		
	At 120 °C		
	Hardness Decrease	IRHD	0 to 15
	Volume Increase	%	0 to 10
	Blisters	--	None
	Sloughing	--	None
5.12	**Resistance to Friction-Induced Noise**		
	Stick-slip oscillations, sigma		<0.005
	Static friction coefficient, SFC		Report

5. TEST PROCEDURES

5.1 Equilibrium Reflux Boiling Point

Determine the equilibrium reflux boiling point of the brake fluid by ASTM D1120 with the following exceptions:

5.1.1 Apparatus

5.1.1.1 Thermometer

ASTM E1, 76 mm immersion, calibrated. Use ASTM 3C or 3F thermometer. For fluids boiling below 300 °C (572 °F), ASTM 2C or 2F thermometer or other suitable non-mercury containing temperature measuring device, such as a thermocouple, capable of operating in the same temperature range and having equal or better accuracy may be used.

5.1.1.2 Heat Source

Heat source, variable autotransformer-controlled heating mantle designed to fit the flask, or an electric heater with rheostat heat control.

5.1.1.3 Boiling Point Stones RM-75

Silicon carbide boiling stones #8.

5.1.1.4 Preparation of Apparatus

Thoroughly clean and dry all glassware before use. Attach the flask to the condenser. Place the mantle under the flask and support it with a suitable ring clamp and laboratory type stand, holding the whole assembly in place by a clamp.

NOTE: Place the whole assembly in an area free from drafts or other types of sudden temperature changes.

5.1.2 Procedure

When everything is in readiness, turn on the condenser water and apply heat to the flask at such a rate that the fluid is refluxing in 10 minutes ± 2 minutes at a rate in excess of 1 drop/s.

Immediately adjust heat input to obtain a specified equilibrium reflux rate of 1 to 2 drop/s over the next 5 minutes ± 2 minutes. Maintain a timed and constant equilibrium reflux rate of 1 to 2 drop/s for an additional 2 minutes; record the average value of four temperature readings taken at 30-second intervals as the equilibrium reflux boiling point.

5.1.3 Repeatability (Single Analyst)

The standard deviation of results (each the average of duplicates), obtained by the same analyst on different days, has been estimated to be 0.4 °C (0.88 °F) at 72 degrees of freedom. Two such values should be considered suspect (95% confidence level) if they differ by more than 1.5 °C (2.5 °F).

5.1.4 Reproducibility (Multilaboratory)

The standard deviation of results (each the average of duplicates), obtained by analysts in different laboratories, has been estimated to be 1.8 °C (3.02 °F) at 17 degrees of freedom. Two such values should be considered suspect (95% confidence level) if they differ by more than 5 °C (9 °F).

5.2 Wet Equilibrium Reflux Boiling Point

5.2.1 Humidification Procedure

Lubricate the ground-glass joint of a 250 mm (9.89 inches) ID bowl-form desiccator having matched tubulated glass cover and fitted with a No. 8 rubber stopper. Pour 450 mL ± 10 mL of distilled water into the desiccator and insert a perforated porcelain plate (Coors No. 60456 or equivalent). Immediately place one open RM-49 corrosion test jar containing 350 mL ± 5 mL of the test brake fluid into the desiccator. Place a second open RM-49 corrosion test jar containing 350 mL ± 5 mL of TEGME (triethylene glycol monomethyl ether, brake fluid grade; see Appendix E) (RM-71) into the same desiccator. The water content of the TEGME control fluid at the start of exposure shall have been adjusted to 0.50% ± 0.05% by weight (Karl Fischer analysis or equivalent). Replace desiccator cover and insert at once into an ASTM E145, Type II A, forced ventilation oven set at 50 °C ± 1 °C (122 °F ± 1.8 °F).

Periodically, during oven humidification, determine water content of the control fluid. When the water content of the control fluid has reached 3.70% ± 0.05% by weight, remove the desiccator from the oven and seal the test sample. Allow the sealed jar to cool for 60 to 90 minutes at 23 °C ± 5 °C (73.4 °F ± 9 °F).

5.2.2 Wet Equilibrium Reflux Boiling Point

Humidify the brake fluid as described in 5.2.1 and determine the boiling point of the humidified brake fluid as described in 5.1.

5.3 Viscosity

Determine the kinematic viscosity of the fluid by ASTM D445.

5.3.1 Report the viscosity to the nearest mm^2/s (centistokes). Duplicate runs which agree within 1.2% relative to test result are acceptable for averaging (95% confidence level).

5.3.2 Repeatability (Single Analyst)

The coefficient of variation of results (each the average of duplicates), obtained by the same analyst on different days, has been estimated to be 0.4% at 47 degrees of freedom. Two such values should be considered suspect (95% confidence level) if they differ by more than 1.2%.

5.3.3 Reproducibility (Multilaboratory)

The coefficient of variation of results (each the average of duplicates), obtained by analysts in different laboratories, has been estimated to be 1% at 15 degrees of freedom. Two such values should be considered suspect (95% confidence level) if they differ by more than 3%.

5.4 pH Value

Mix the fluid with an equal volume of a mixture of 50% ethanol and 50% distilled water neutralized to a pH of 7.0. Determine the pH of the resulting solution electrometrically at 23 °C ± 5 °C (73.4 °F ± 9 °F) using a pH meter equipped with a calibrated full range (0 to 14) glass electrode and a calomel reference electrode, as specified in ASTM D664.

5.5 Fluid Stability

5.5.1 High-Temperature Stability

Heat a new sample of the original test brake fluid to a temperature of 185 °C ± 2 °C (365 °F ± 3.6 °F) by the procedure specified in 5.1 and maintain at that temperature for 2 hours. Then, determine the boiling point of this brake fluid as specified in 5.1. The difference between this observed boiling point and that previously determined in 5.1 shall be considered as the change in boiling point of the brake fluid.

5.5.2 Chemical Stability

Mix 30 mL of test brake fluid with 30 mL of SAE compatibility fluid described in Appendix B (RM-66-07/ISO 4926). Determine the equilibrium reflux boiling point of this fluid mixture by use of the test apparatus specified in 5.1, applying heat to the flask at such a rate that the fluid is refluxing in 10 minutes ± 2 minutes at a rate in excess of 1 drop/s. The reflux rate shall not exceed 5 drops/s. Record the maximum fluid temperature observed during the first minute after the fluid begins refluxing at a rate in excess of 1 drop/s. Over the next 15 minutes ± 1 minute, adjust and maintain the rate of reflux to 1 to 2 drops/s. Maintain a timed and constant equilibrium reflux rate of 1 to 2 drops/s for an additional 2 minutes; record the average value of four temperature readings taken at 30-second intervals as the final equilibrium reflux boiling point. Chemical reversion is evidenced by the decrease in temperature between the maximum fluid temperature recorded and the final equilibrium reflux boiling point.

5.6 Corrosion

5.6.1 Wet Fluid Corrosion Test

Prepare two sets of strips from each of the metals listed in Appendix A, each strip having a surface area of 25 cm^2 ± 5 cm^2 (approximately 8 cm long, 1.3 cm wide, and not more than 0.6 cm thick). Drill a hole between 4 and 5 mm in diameter and about 6 mm from one end of each strip. With the exception of the tinned iron and the zinc-plated steel strips, clean the strips by abrading them on all surface areas with 320A (RM-29) or P400 waterproof carborundum paper and isopropanol or ethanol until all surface scratches, cuts, and pits are removed from the strips, using a new piece of carborundum paper for each different type of metal. Wash the strips, including the tinned iron and the zinc-plated steel, with isopropanol or ethanol and dry the strips with a clean, lint-free cloth and place strips in a desiccator containing desiccant maintained at 23 °C ± 5 °C (73.4 °F ± 9 °F) for at least 1 hour.

Handle the strips with gloves, or clean forceps or cotton cloths, after polishing to avoid fingerprint contamination.

Weigh each strip to the nearest 0.1 mg and assemble each set of strips on an uncoated steel bolt (RM-61) in the order tinned iron, steel, aluminum, cast iron, brass, copper, and zinc-plated steel so that the strips are in electrical contact. Bend the strips, other than cast iron, so that there is a separation of at least 3 mm between adjacent strips for a distance of about 6 cm from the free end of the strips.

Use two SBR cups (RM-03a) and two 25.4 x 25.4 mm (1 x 1 inch) EPDM rubber slab stock (RM-69-02) test specimens.

Measure the base diameter of the two standard SBR cups (RM-03a), described in Appendix C, using an optical comparator or micrometer to the nearest 0.02 mm (0.001 inch) along the centerline of the SAE and rubber type identifications and at right angles to this centerline. Take the measurements within 0.4 mm (0.015 inch) of the bottom edge and parallel to the base of the cup. Discard any cup if the two measured diameters differ by more than 0.08 mm (0.003 inch). Average the two readings of each cup. Support the rubber cup on a rubber anvil or cylinder having a flat circular top surface of at least 19 mm in diameter, a thickness of at least 9 mm, and a hardness within five IRHD of the hardness of the rubber test cup. Determine the hardness of each cup thus supported by the procedure specified in ASTM D1415 using the standard tester.

NOTE: ASTM D2240 may be used for quality control and routine tests when a Type A durometer is equipped with a fixture for keeping the plane of the pressure foot on the durometer parallel to the plane of the cup face during measurement.

Determine the slab hardness. Determine the weight of the EPDM rubber slab stock in air (m_1) to the nearest 1 mg, then determine the apparent weight of the slab stock immersed in distilled water at room temperature (m_2). Quickly dip each specimen in alcohol and then blot dry with filter paper free of lint and foreign matter.

Obtain two straight-sided round glass jars having a capacity of approximately 475 mL and inner dimensions of approximately 100 mm in height and 75 mm in diameter (RM-49). To the RM-49 corrosion test jar, apply four wrappings of 19 mm (3/4 inch) Teflon tape around the jar threads, allowing a 3 mm (1/8 inch) height above the top of the jar. Place one SBR cup (RM-03a) with lip edge facing up in each of the two glass jars. Use only tinned steel lids vented with a hole 0.8 mm ± 0.1 mm in diameter (RM-64).

Insert a metal strip assembly inside each cup with the bolted end in contact with the concavity of the cup and the free end extending upward in the jar. Place one EPDM rubber slab stock (RM-69-02) test specimen flat on the bottom of the test jar. Mix 760 mL of test fluid with 40 mL of distilled water. Add 400 mL of the test fluid/water mixture to cover the metal strip assembly in each jar. Tighten the lid and place the jars in an oven maintained at 100 °C ± 2 °C (212 °F ± 3.6 °F) for 120 hours ± 2 hours.

Allow the jars to cool at 23 °C ± 5 °C (73.4 °F ± 9 °F) for 60 to 90 minutes.

Immediately following the cooling period, remove the metal strips from the jars by use of a forceps, removing loose adhering sediment by agitation of the metal strip assembly in the fluid in the jar, and remove the rubber cups from the jars by use of a forceps, removing loose adhering sediment by agitation of the cup in the fluid in the jar. Rinse cups in isopropanol or ethanol and air-dry cups. Examine test strips and test jars for adhering crystalline deposit, disassemble the metal strips, removing adhering fluid by flushing with water, and clean individual strips by wiping with a cloth wetted with isopropanol or ethanol. Examine the strips for evidence of corrosion and pitting. Place strips in a desiccator containing a desiccant maintained at 23 °C ± 5 °C (73.4 °F ± 9 °F) for at least 1 hour.

Within 15 minutes after removal from the fluid, weigh each EPDM rubber slab stock (RM-69-02) in air (m_3), again to the nearest milligram, then reweigh immersed in room temperature distilled water (m_4) to determine the volume change after hot fluid immersion. Determine the slab hardness.

Within 15 minutes after removing the cups from the fluid, visually examine each cup for evidence of sloughing, blisters, and other forms of disintegration. Measure the base diameter and hardness of each cup.

After 1 hour in the desiccator, metal strips are weighed to the nearest 0.1 mg. Determine the difference in weight of each metal strip and divide the difference by the total surface area of the metal strip measured in square centimeters. Average the measured quantities of the duplicates. In the event of a marginal pass on inspection, or of a failure in only one of the duplicates, another set of duplicate test samples shall be run. Both repeat samples must meet all the requirements in 5.6.

Examine the fluid in the jars for gelling. Agitate the fluid in the jars to suspend and uniformly disperse sediment and transfer a 100 mL portion of this fluid to an ASTM cone-shaped centrifuge tube and determine percent sediment as described in 8.2 of ASTM D91. Measure the pH value of the corrosion test fluid by the procedure specified in 5.4.

Measure the hardness of each specimen. Volume changes shall be reported as a percentage of the original volume, calculated as follows:

$$\text{\% change in volume} = \frac{(m_3 - m_4) - (m_1 - m_2)}{(m_1 - m_2)} \times 100 \quad \text{(Eq. 1)}$$

where:

m_1 = initial mass, in grams, in air

m_2 = initial mass, in grams, in water

m_3 = mass, in grams, in air after immersion in test fluid

m_4 = apparent mass, in grams, in water after test

5.6.2 Dry Fluid Corrosion Test

Prepare and weigh two sets of metal test strips as detailed in 5.6.1.

Use two SBR cups (RM-03a), and two 25.4 x 25.4 mm (1 x 1 inch) EPDM rubber slab stock (RM-69-02) test specimens, as described in Appendices C and D, respectively.

Obtain two straight-sided round glass jars having a capacity of approximately 475 mL and inner dimensions of approximately 100 mm in height and 75 mm in diameter (RM-49). To the RM-49 corrosion test jar, apply four wrappings of 19 mm (3/4 inch) Teflon tape around the jar threads, allowing a 3 mm (1/8 inch) height above the top of the jar. Place one SBR cup (RM-3a) with lip edge facing up in each of the two glass jars. Use only tinned steel lids vented with a hole 0.8 mm ± 0.1 mm in diameter (RM-64).

Insert a metal strip assembly inside each cup with the bolted end in contact with the concavity of the cup and the free end extending upward in the jar. Place one EPDM rubber slab stock (RM-69-02) test specimen flat on the bottom of the test jar. Add 400 mL of dry test fluid to cover the metal strip assembly in each jar. Tighten the lid and place the jars in an oven maintained at 100 °C ± 2 °C (212 °F ± 3.6 °F) for 120 hours ± 2 hours.

Allow the jars to cool at 23 °C ± 5 °C (73.4 °F ± 9 °F) for 60 to 90 minutes.

Immediately following the cooling period, remove the metal strips from the jars by use of a forceps, removing loose adhering sediment by agitation of the metal strip assembly in the fluid in the jar. Rinse cups in isopropanol or ethanol and air-dry cups. Examine test strips and test jars for adhering crystalline deposit, disassemble the metal strips, removing adhering fluid by flushing with water, and clean individual strips by wiping with a cloth wetted with isopropanol or ethanol. Examine the strips for evidence of corrosion and pitting. Place strips in a desiccator containing a desiccant maintained at 23 °C ± 5 °C (73.4 °F ± 9 °F) for at least 1 hour.

After 1 hour in the desiccator, metal strips are weighed to the nearest 0.1 mg. Determine the difference in weight of each metal strip and divide the difference by the total surface area of the metal strip measured in square centimeters. Average the measured quantities of the duplicates. In the event of a marginal pass on inspection, or of a failure in only one of the duplicates, another set of duplicate test samples shall be run. Both repeat samples must meet all the requirements of 5.6.

Immediately following the cooling period, remove the rubber specimens from the jars by use of a forceps, removing loose adhering sediment by agitation of the cup in the fluid in the jar. Visually examine each cup for evidence of sloughing, blisters, and other forms of disintegration.

Examine the fluid in the jars for gelling. Measure the pH value of the corrosion test fluid by the procedure specified in 5.4. Agitate the fluid in jars to suspend and uniformly disperse sediment and transfer a 100 mL portion of this fluid to an ASTM cone-shaped centrifuge tube and determine percent sediment as described in 8.2 of ASTM D91.

5.7 Fluidity and Appearance at Low Temperature

5.7.1 At -40 °C (-40 °F)

Place 100 mL of the test fluid in a glass sample bottle (RM-59a) having a capacity of approximately 125 mL, an outside diameter of 37 mm ± 0.5 mm, and an overall height of 165 mm ± 3 mm. Stopper or cap the bottle tightly and place in a freezer[1] maintained at -40 °C ± 2 °C (-40 °F ± 3.6 °F) for 144 hours ± 4 hours. Remove the bottle from the freezer, quickly wipe the bottle with a clean, lint-free cloth saturated with isopropanol or ethanol, and examine the fluid for evidence of stratification, sediment, or crystals. Invert the bottle and determine the number of seconds required for the air bubble to travel to the top of the fluid. Allow the fluid to warm to room temperature 23 °C ± 5 °C (73 °F ± 9 °F); if necessary, allow to stand for as long as 4 hours. Examine the fluid for clarity and appearance by comparing it to an original sample of the test fluid in an identical container.

[1] See Appendix G for recommendations on placing samples in the freezer.

5.7.2 At -50 °C (-58 °F)

Place 100 mL of fluid in a glass sample bottle (same as in -40 °C test above). Stopper or cap the bottle tightly and place in a freezer maintained at -50 °C ± 2 °C (-58 °F ± 3.6 °F) for 6 hours ± 0.2 hour. Remove the bottle from the freezer, quickly wipe the bottle with a clean, lint-free cloth saturated with isopropanol or ethanol, and examine the fluid for evidence of stratification, sediment, or crystals. Invert the bottle and determine the number of seconds required for the air bubble to travel to the top of the fluid. Allow the fluid to warm to room temperature 23 °C ± 5 °C (73 °F ± 9 °F); if necessary, allow to stand for as long as 4 hours. Examine the fluid for clarity and appearance by comparing it to a sample of the original test fluid in an identical container.

5.8 Water Tolerance

5.8.1 At -40 °C (-40 °F)

Mix 96.5 mL of test fluid and 3.5 mL of distilled water into an ASTM cone-shaped centrifuge tube, described in 5.1 of ASTM D91. Stopper the tube with a cork and place in a freezer maintained at -40 °C ± 2 °C (-40 °F ± 3.6 °F) for 22 hours ± 2 hours. Remove the centrifuge tube from the freezer, quickly wipe the tube with a clean, lint-free cloth saturated with isopropanol or ethanol, and determine the transparency of the fluid by placing the tube against a hiding power test chart (RM-28) and observing the clarity of the contrast lines on the chart when viewed through the fluid. Examine the fluid for evidence of stratification and sedimentation. Invert the tube and determine the number of seconds required for the air bubble to travel to the top of the fluid. The air bubble shall be considered to have reached the top of the fluid when the top of the bubble reaches the 2 mL graduation of the centrifuge tube.

5.8.2 At 60 °C (140 °F)

Place the centrifuge tube from 5.8.1 in an oven maintained at 60 °C ± 2 °C (140 °F ± 3.6 °F) for 22 hours ± 2 hours. Remove the tube from the oven and immediately examine the contents for evidence of stratification. Determine percent sediment by volume as described in 8.2 of ASTM D91.

5.9 Compatibility

5.9.1 At -40 °C (-40 °F)

Mix 50 mL of fluid with 50 mL of SAE compatibility fluid, described in Appendix B (RM-66-07/ISO 4926), and pour this mixture into an ASTM cone-shaped centrifuge tube, described in 5.1 of ASTM D91, and stopper with a cork. Place centrifuge tube for 22 hours ± 2 hours in a freezer maintained at -40 °C ± 2 °C (-40 °F ± 3.6 °F). Remove the centrifuge tube from the freezer, quickly wipe the tube with a clean, lint-free cloth saturated with isopropanol or ethanol, and determine the transparency of the fluid by placing the tube against a hiding power test chart (RM-28) and observing the clarity of the contrast lines on the chart when viewed through the fluid. Examine the fluid for stratification and sedimentation.

5.9.2 At 60 °C (140 °F)

Place the centrifuge tube from 5.9.1 in an oven at 60 °C ± 2 °C (140 °F ± 3.6 °F) for 22 hours ± 2 hours. Remove the tube from the oven and immediately examine the contents for evidence of stratification. Determine percent sediment by volume as described in 8.2 of ASTM D91.

5.10 Resistance to Oxidation

Prepare two sets of aluminum and cast-iron test strips (RM-08 and RM-09) by the procedure specified in 5.6. Weigh each strip to the nearest 0.1 mg and assemble a strip of each metal on an uncoated steel bolt (RM-62), separating the strips at each end with a piece of tinfoil (RM-27) (minimum 99.5% tin, maximum 0.5% lead) approximately 12 mm square and between 0.02 mm and 0.06 mm in thickness.

Place 30 mL ± 1 mL of fluid in a small glass bottle approximately 120 mL in capacity. Add 60 mg ± 2 mg of reagent grade benzoyl peroxide as per ASTM E298 and 1.5 mL ± 0.05 mL distilled water to the bottle. Stopper the bottle and shake the contents, avoiding getting the solution on the stopper. Place the bottle in an oven at 70 °C ± 2 °C (158 °F ± 3.6 °F) for 120 minutes ± 10 minutes, shaking every 15 minutes to effect solution of the peroxide. Remove the bottle from the oven, do not disturb the stopper, and cool in air at room temperature, 23 °C ± 5 °C (73 °F ± 9 °F).

Place approximately 1/8 section of a standard SBR cup, described in Appendix C (RM-03a), in the bottom of each of two test tubes about 22 mm in diameter and 175 mm in length. Add 10 mL of prepared test fluid to each test tube. Place a metal strip assembly in each tube with the end of the strips resting on the rubber, the solution covering about one-half the length of the strips, and the bolted end remaining out of the solution. Stopper the tubes with corks and store upright for 22 hours ± 2 hours at 23 °C ± 5 °C (73.4 °F ± 9 °F). Loosen the stoppers and place the tubes for 168 hours ± 2 hours in an oven maintained at 70 °C ± 2 °C (158 °F ± 3.6 °F). After the heating period, remove from the oven and allow to cool to room temperature for 60 to 90 minutes. Remove and disassemble the metal strips. Examine the strips for gum deposits. Wipe the strips with a cloth wet with isopropanol or ethanol and examine for pitting or roughening of surface. Place strips in desiccator containing a desiccant maintained at 23 °C ± 5 °C (73.4 °F ± 9 °F) for at least 1 hour. Weigh each strip to the nearest 0.1 mg.

Determine corrosion loss by dividing the difference in weight of each metal strip by the total surface area of each metal strip measured in square centimeters. Average the measured quantities of the duplicates. In the event of a marginal pass on inspection, or of a failure in only one of the duplicates, another set of duplicate test samples shall be run. Both repeat samples must meet all the requirements in 5.6.

5.11 Effect on Rubber

For the test procedure in 5.11.1, use standard SBR cups, described in Appendix C (RM-03a). Measure the base diameter of all cups and hardness of all specimens as described in 5.6, discarding any cups whose diameters differ by more than 0.08 mm (0.003 inch).

For the test procedure in 5.11.2, cut 25.4 x 25.4 mm (1 x 1 inch) test specimens from standard EPDM slab stock, as described in Appendix D (RM-69-02). Determine volume of each in the following manner:

Weigh the specimen in air (M_1) to the nearest milligram and then weigh the specimens immersed in room temperature distilled water (M_2) containing no more than 0.2% of a suitable wetting agent. Pluronic L-61 (BASF) or equivalent has been found to be acceptable.

Determine hardness of each specimen as described in 5.6.

5.11.1 Test at 120 °C (248 °F)

Place two standard SBR cups (RM-03a) in a straight-sided round glass jar (RM-51) having a capacity of approximately 250 mL and inner dimensions of approximately 125 mm in height and 50 mm in diameter, and a tinned steel lid (RM-52a). Add 75 mL of fluid to the jar and heat for 70 hours ± 2 hours at 120 °C ± 2 °C (248 °F ± 3.6 °F). Allow the jar to cool at 23 °C ± 5 °C (73.4 °F ± 9 °F) for 60 to 90 minutes. Remove the cups from the jar, wash quickly with isopropanol or ethanol, and air-dry cups. Examine the cups for disintegration as evidenced by blisters or sloughing. Measure the base diameter and hardness of each cup within 15 minutes after removal from the fluid.

5.11.2 Test at 120 °C (248 °F)

Place two 25.4 x 25.4 mm (1 x 1 inch) standard EPDM test specimens (RM-69-02) in a straight-sided round glass jar having a capacity of approximately 250 mL and inner dimensions of approximately 125 mm in height and 50 mm in diameter, and tinned steel lid (RM-52a). Add 75 mL of fluid to the jar and heat for 70 hours ± 2 hours at 120 °C ± 2 °C (248 °F ± 3.6 °F). Allow the jar to cool to 23 °C ± 5 °C (73.4 °F ± 9 °F) for 60 to 90 minutes. Remove the specimens from the jar, wash quickly with isopropanol or ethanol, and air-dry. Examine the specimens for disintegration as evidenced by blisters or sloughing. Determine the volume change, calculated per Equation 1, shown in 5.9.1. Measure the hardness of each specimen.

Report the rubber swell to the nearest 0.03 mm (0.001 inch). Duplicate results which agree within 0.10 mm (0.004 inch) are acceptable for averaging (95% confidence level).

5.11.3 Repeatability for the Base Diameter Increase Measurement (Single Analyst)

The standard deviation of results (each the average of duplicate determinations), obtained by the same analyst on different days, has been estimated to be 0.05 mm (0.002 inch) at 46 degrees of freedom. Two such values should be considered suspect (95% confidence level) if they differ by more than 0.13 mm (0.005 inch).

5.11.4 Reproducibility for the Base Diameter Increase Measurement (Multilaboratory)

The standard deviation of results (each the average of duplicates), obtained by analysts in different laboratories, has been estimated to be 0.08 mm (0.003 inch) at 7 degrees of freedom. Two such values should be considered suspect (95% confidence level) if they differ by more than 0.20 mm (0.008 inch).

5.12 Resistance to Friction-Induced Noise

Determine stick-slip oscillation sigma and static friction coefficient using the method described in DIN 51834-5.

6. NOTES

6.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE BRAKE FLUIDS STANDARDS COMMITTEE

APPENDIX A - STANDARD CORROSION TEST STRIPS

A.1 See Table A1.

Table A1 - Standard corrosion test strips

Corrosion Test Strip	Material Specification	General Material Data	Dimensions	Surface Requirements
Tinned Steel RM-06a	ASTM A624, Federal Specification QQ-T-425A	SR tin plate electrolytic, bright: No. 25, type MR Temper 3, base weight 85 pounds Ferrostand and DOS oil	Approx 8 cm long; 1.3 cm wide Thickness: As purchased Surface area: 25 $cm^2 \pm 5$ cm^2	As sheared. Clean and uniform tinning.
Steel RM-07	SAE 1018	Low carbon sheet Cold rolled Hardness: 40 to 72 RB	Approx 8 cm long; 1.3 cm wide Thickness: Approx 0.2 cm Surface area: 25 $cm^2 \pm 5$ cm^2	Edges machined to remove shearing marks. Clean uniform surfaces.
Aluminum RM-08	SAE AA2024	Wrought aluminum alloy Temper T3 Hardness: 75 RB typical	Approx 8 cm long; 1.3 cm wide Thickness: Approx 0.2 cm Surface area: 25 $cm^2 \pm 5$ cm^2	Edges machined to remove shearing marks. Clean uniform surfaces.
Cast Iron RM-09	SAE G3000	Soft automotive cast iron. Must be free from shrinkage cavities, porosity, or any other defects detrimental to specification use of the material. Hardness: 86 to 98 RB	Approx 8 cm long; 1.3 cm wide Thickness: Approx 0.4 cm Surface area: 25 $cm^2 \pm 5$ cm^2	Surface grind four sides to dimension using a well-dressed No. 80 Alundum wheel. Clean uniform surfaces.
Brass RM-10	SAE CA260	Wrought alloy - yellow brass Rolled sheet or strip; half hard temper Hardness: 57 to 74 RB	Approx 8 cm long; 1.3 cm wide Thickness: Approx 0.2 cm Surface area: 25 $cm^2 \pm 5$ cm^2	Edges machined to remove shearing marks. Clean uniform surfaces.
Copper RM-11	SAE CA114	Cold rolled copper sheet or strip Half-hard temper Hardness: 35 to 56 RB	Approx 8 cm long; 1.3 cm wide Thickness: Approx 0.2 cm Surface area: 25 $cm^2 \pm 5$ cm^2	Edges machined to remove shearing marks. Clean uniform surfaces.
Zinc Plated Steel RM-76	Complete Material Spec. Fe/Zn 13 C1B Steel ISO 3574 Plating ISO 2081 Chromate Treatment ISO 4520	Table 1 Designation CR1 Table C.1 Service Condition number 3 Table 2 Classification 1B 24 hours minimum	Approx 8 cm long; 1.3 cm wide Thickness: Approx 0.2 cm Surface area: 25 $cm^2 \pm 5$ cm^2	As supplied - sheared then electroplated.

Note: Drill hole between 4 and 5 mm in diameter and approximately 6 mm from one end of each strip. Holes to be clean and free from burrs. Hardness ranges are commercially for the designated metals. Hardness is not specified for the tinned iron or the zinc-plated iron because it is not considered a practical requirement.

APPENDIX B - RM-66-07/ISO 4926 COMPATIBILITY FLUID

B.1 FORMULATION OF FLUID

Table B1 - Formulation of fluid

Components	CAS Number	Mass Fraction %	Purity[1]
Borate of triethylene glycol monomethyl ether	30989-05-0	50	Content of boric acid 11.2 to 11.5%
Triethylene glycol monomethyl ether	112-35-6	27.5	≥95%
Tetraethyleneglycol monomethyl ether	23783-42-8	10	>72%
Triethyleneglycol monobutylether	143-22-6	10	60 to 80%
Diisopropanolamine	110-97-4	2	≥98%
Tolyltriazole	29385-43-1	0.5	≥98%

(1) The water content of the reference fluid shall be less than or equal to 0.20%.

The reference fluid RM-66-07 has a minimum shelf life of 5 years when purchased and stored in accordance with SAE J75.

APPENDIX C - STANDARD STYRENE-BUTADIENE RUBBER (SBR) BRAKE CUPS FOR TESTING SAE MOTOR VEHICLE BRAKE FLUIDS

C.1 FORMULATION OF RUBBER COMPOUND

Table C1 - Formulation of rubber compound

Ingredient	Parts by Weight
SBR Type 1502	100
N330	42
BBTS Pellets	1
St. Acid Pristerine 9429	1
Zinc Oxide (210/672)	5
Polydex E (DCP-R) 40 D	4.5
Spider Sulfur MC98	0.25
AGRTE Stalite S/Octamine	1
Antiox 58/ZMTI PDR	0.5
Flexone6H CCPD/*Vanox 6H	1.5
TOTAL	156.75

C.2 PROCEDURE FOR MIXING RUBBER COMPOUND

The rubber compound shall be mixed in accordance with the procedure given in ASTM D3185 for Formula 2B.

C.3 PROPERTIES OF RUBBER COMPOUND

Vulcanizates of slab stock cured for 12 minutes at 180 °C (356 °F) followed by a post cure for 4 hours at 100 °C (212 °F) by the procedure described in ASTM D3182 shall meet the requirements in Table C2.

Table C2 - Properties of rubber compound

Property	Requirement	ASTM Method
Hardness	63 ± 3	D1415 or D2240
Tensile strength	17.5 MPa (2500 f-lb/in^2, min)	D412
Ultimate elongation	350%, min	D412
Tensile strength after 70 hours at 125 °C (257 °F)	30% decrease, max	D865
Ultimate elongation after 70 hours at 125 °C (257 °F)	50% decrease, max	D865
Hardness after 70 hours at 125 °C (257 °F)	0 to 10 increase	D865
Compression set after 22 hours at 125 °C (257 °F)	10 to 20%	D395 (Method B)
Brittleness temperature	-40 °C (-40 °F), max	D2137